
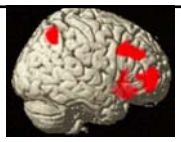


Music as a window to the creating brain

Fredrik Ullén, Dept of Neuroscience, Karolinska Institutet
East-West Connections, Singapore, 2016


Why we study the neuroscience of music and other art forms

- Intrinsically interesting – neuroaesthetics
- Interventions
- Model behaviors for cognition in general
  - → Sensory discrimination
  - → Motor performance and coordination
  - → Emotion
  - → Social cognition
  - → Executive control
  - → Skill learning and expertise
  - → Creativity
  - → etc

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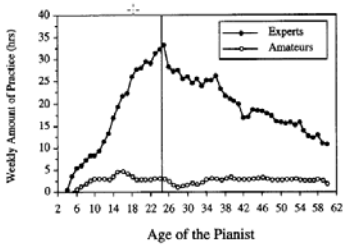
  - → **Creativity**
  - → etc

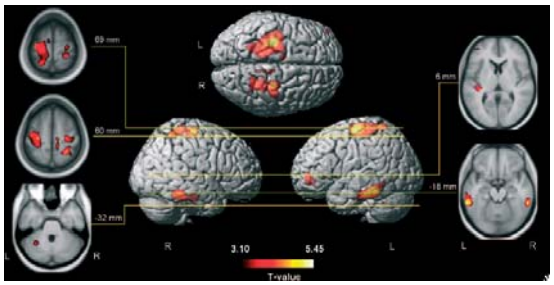
Music training and the brain

Training and expert performance



Krampe and Ericsson (1996), J Exp Psychol: General

Gray matter in musicians



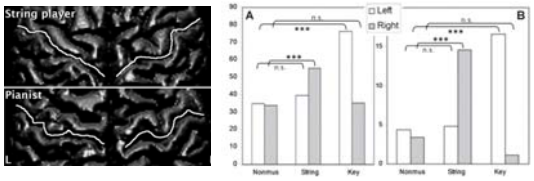
Gaser and Schlaug (2003), J Neurosci

Specific gray matter effects of different musical training

”Omega Sign” (OS) in precentral gyrus

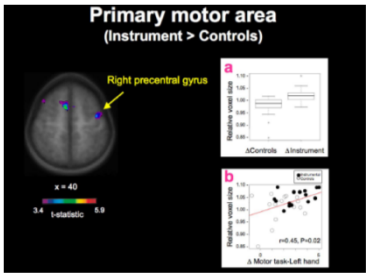
OS-1 or OS-2

OS-2



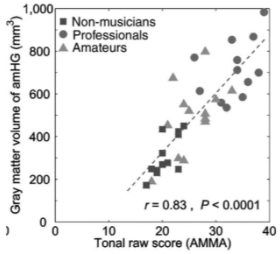
Bangert and Schlaug (2006), Eur J Neurosci

Musical training and gray matter – longitudinal data



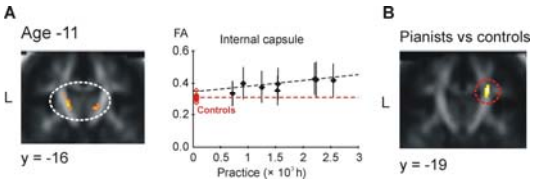
Hyde et al (2009), J Neurosci

Regional gray matter structure and performance



Schneider et al (2002), Nat Neurosci

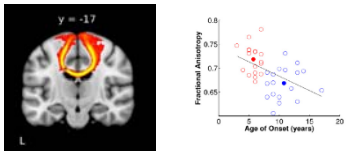
White matter in musicians



Bengtsson et al (2005), Nat Neurosci

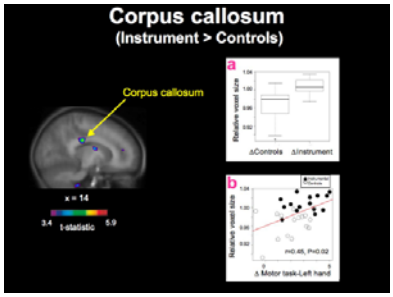
White matter in musicians

More well-organized corpus callosum in early trained musicians



Steele et al (2013), J Neurosci

Musical training and white matter – longitudinal data



Hyde et al (2009), J Neurosci

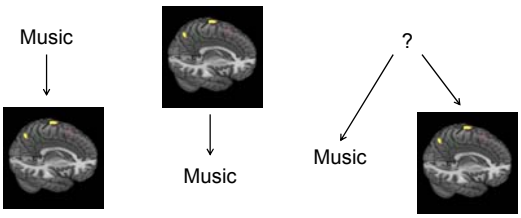
Summary

- Musical training is correlated with brain anatomy
  - →Gray matter (regional volume, cortical thickness)
  - →White matter (organization, connectivity)
- Neuroanatomical effects are specific to type of musical training
  - →Expertise-related
- Longitudinal data show differences developing over time in trainers versus non-trainers

Training effects – the problem of causality

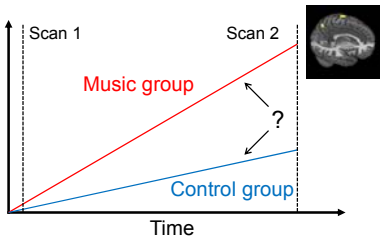
The problem of causality 1

- Cross-sectional data
- Many causal scenarios are possible



The problem of causality 2

- Observational longitudinal studies



The problem of causality 3

- Randomized longitudinal studies
- Ideal in principle
- Practically difficult/impossible in expertise studies
  - →Months/years of dedicated practice

Case in point: music training and "musical ear"

- "Musical ear" = musical auditory discrimination
- Ability to discriminate rhythms, melodies, pitches etc

- Positively related to musical training
- Musicians outperform non-musicians
- Commonly assessed in entrance exams to music colleges

Humans making music

Web-based data collection (finished feb 2013)
- responses from > 10,500 twin individuals

- **Music training**
- Musical childhood environment

- **Musical auditory discrimination**
- General IQ, reaction time

- Creative achievement (7 domains)

- General personality (Big Five), schizotypy
- Intrinsic and extrinsic motivation (GSM)
- Occupational preferences
- Proneness for flow experiences

- General psychological and somatic health
- Emotional processing (alexithymia)

What drives the association between training and musical ear?

- Participants
  - →1211 monozygotic ("identical") pairs (MZ)
  - →1358 dizygotic pairs (DZ)
  - →5401 single twin individuals
- Measures
  - →Total hours of musical practice
  - →Swedish Music Discrimination Test (SMDT)
    - Melodies
    - Rhythms
    - Pitches

Mosing et al (2014), Psychol Sci

Musical training and music discrimination

	Melody	Rhythm	Pitch
Training	.32	.22	.34
Melody		.39	.39
Rhythm			.31

5-12% of variance in ability explained by training
– other things matter!

Mosing et al (2014), Psychol Sci

Twin modelling

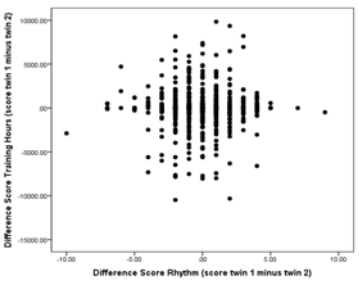
- Classical twin design
  - →Compare MZ and DZ twins
  - →Partition phenotypic variance and covariance into:
    - A: Additive genetic effects
    - C: Shared environment
    - E: Non-shared environment

Genetic factors influence training and musical abilities

	Melody	Rhythm	Pitch	Heritability
Training	.32	.22	.34	.57
Melody		.39	.39	.58
Rhythm			.31	.50
Pitch				.39

Mosing et al (2014), Psychol Sci

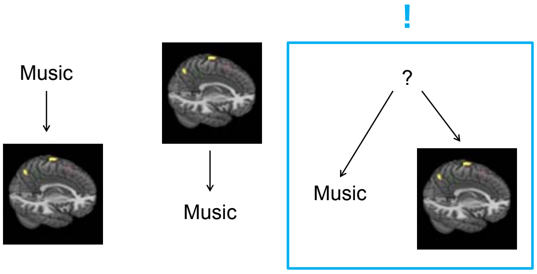
Musical training and music discrimination ability



No significant within-pair relations for any of the music discrimination scales (*r* values .00 - .08)

Mosing et al (2014), Psychol Sci

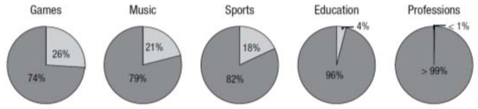
What drives the association between training and musical ear?



Mosing et al (2014), Psychol Sci

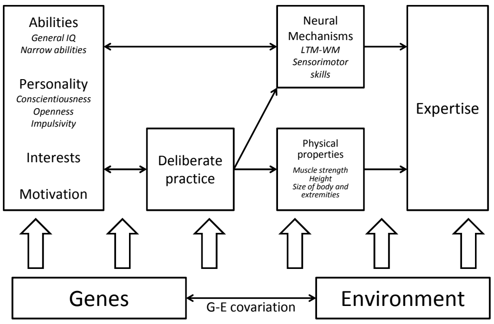
Practice and expert performance - metaanalyses

- Deliberate practice only explains a moderate proportion of variance in expert performance



Macnamara et al (2014), Psychol Sci

Multifactorial Gene-environment Interaction Model (MGIM) of expertise



Ullén, Hambrick, and Mosing (2016), Psychol Bull

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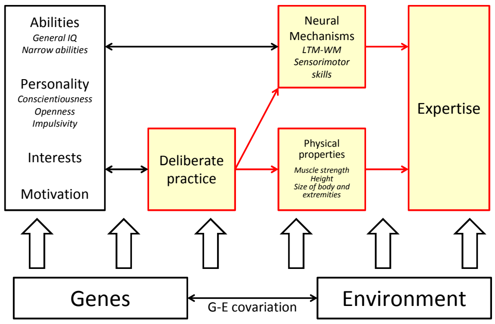

Ullén, Hambrick, and Mosing (2016), Psychol Bull

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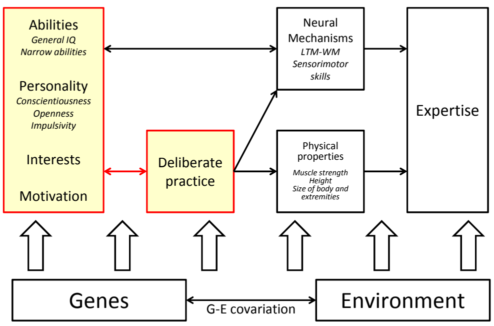

Ullén, Hambrick, and Mosing (2016), Psychol Bull

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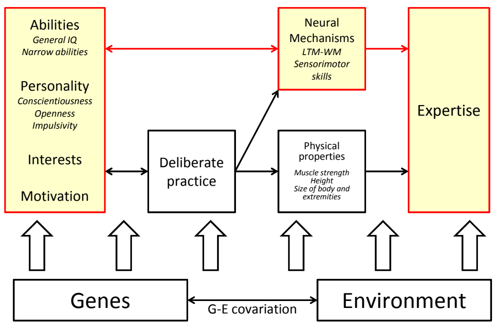

Ullén, Hambrick, and Mosing (2016), Psychol Bull

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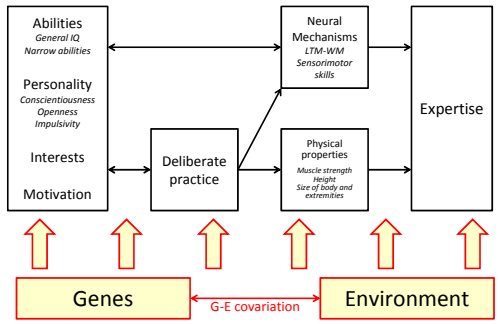
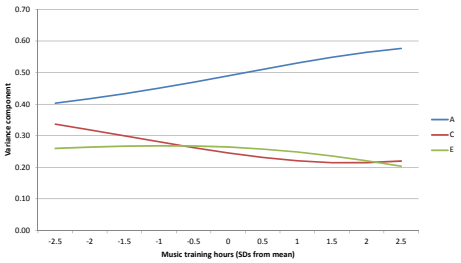


Ullén, Hambrick, and Mosing (2016), Psychol Bull

Genetic influences on musical discrimination *increase* with training

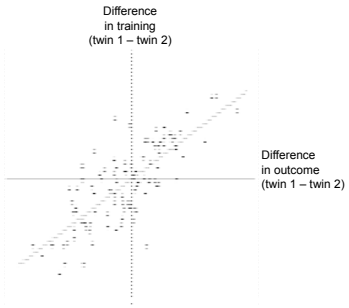


Verweij, Mosing et al (under review)

How can we get at causal effects of long-term training in expertise?

Monozygotic twins – intrapair difference model

If training *causes* an outcome, we would expect →



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- Musical perceptual abilities (pitch, rhythm, melody)
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- Emotional processing (alexithymia)

→ Experimental studies on smaller sample of extremely discordant MZs

Monozygotic twins discordant for piano practice

- 10 pairs with > 1300 h intrapair difference in piano practice (recruited from all over Sweden)
- "playing twin": still active
- "non-playing twin": no practice in adulthood
- all right-handed

Experiments

- Interviews
- Working memory tests
- Finger force control tests
- MR scanning
  - →Brain anatomy (structural MRI)
    - Gray matter, diffusion MRI
  - →Functional MRI
    - Sequence production, perception, improvisation

Why did the twins differ in musical engagement?

- Psychological questionnaire data
  - →Personality
    - Playing twin higher in Openness
  - →Enjoying music
    - Playing twin more frequent psychological flow experiences during musical activities

Eriksson et al (in press), Musicae Scientiae

Why did the twins differ in musical engagement? - Interviews

- Semi-structured interviews with five main themes
  - →Own thoughts about why they became discordant
  - →Childhood differences in "musical environment"
    - music listening, music teachers, music interest of peers, parental engagement, public performing
  - →Strong memories of music
  - →Significance of music in your life
  - →Interest and skills in language

Eriksson et al (in press), Musicae Scientiae

Why did the twins differ in musical engagement? - Interviews

- Playing twin
  - →More elaborate answers about meaning of music in life, emphasizing importance for personal identity
- No systematic within-pair differences in self-reported
  - →interests of peers, parental support, music teacher, ensemble playing, public performances, interest and aptitude for languages

Eriksson et al (in press), Musicae Scientiae

Why did the twins differ in musical engagement? - Interviews

- Reported possible reasons for discordance idiosyncratic and unique for each pair, e.g.:
  - →Different access to the piano
  - →Different feelings about music genre played at home
  - →Different needs for creative hobbies
  - →Different feelings about the music teacher
  - →Different attitudes to music as an expression of faith
  - →Music-playing parent role model for one but not other twin
  - →etc
- When controlling for genes and shared environment, remaining influences are "unsystematic" in nature

Eriksson et al (in press), Musicae Scientiae

Summary

- Discordant monozygotic twins provide a unique opportunity to study "pure training effects" (i.e. independent of genetic factors and common environment)
- Trained twin
  - →Larger regional gray matter volume of left temporo-parietal junction
  - →Higher fractional anisotropy in left pyramidal tract of playing twin
  - →Higher working memory capacity for musical materials

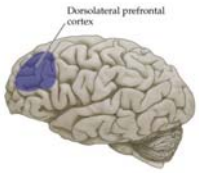
Music as a window to the creating brain

Improvisation as a model for creative performance

- Ecologically valid
- Possible to study with brain imaging (simplified!)

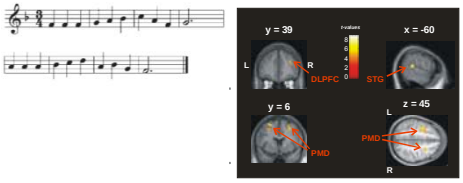
What is the role of the DLPFC for improvisation?

- Dorsolateral prefrontal cortex (DLPFC)
  →Attention, working memory, selection



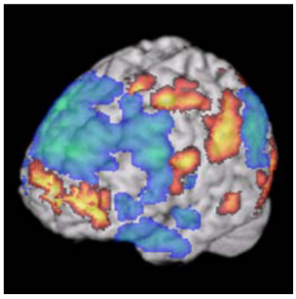
The DLPFC is activated when classical pianists improvise

- Improvisation (ornaments) versus from memory
  (Bengtsson et al, 2007; J Cogn Neurosci)



- Improvisation versus playing from score
  (de Manzano et al, 2012; NeuroImage)

The DLPFC is *deactivated* during jazz improvisation in jazz pianists



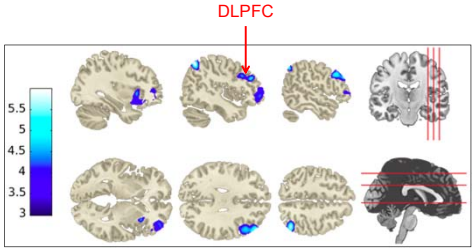
Limb and Braun (2008), PLoS One

Improvisation training and the brain

- Is specific jazz expertise one factor behind these findings?
  →Does training improvisation have specific effects over and above classical piano training?
- 39 pianists (varied jazz/classical background)
- Brain activity during brief improvisations
- Associations with improvisation training (controlling for classical training)

Pinho et al (2014), J Neurosci

Improvisation training negatively correlated with DLPFC activity during improvisation



Pinho et al (2014), J Neurosci

Summary

- The involvement of the DLPFC in improvisation is lower for experienced improvisers
- Characteristics of the task also matter! (Pinho et al, 2015, Cereb Cortex)
  - Improvise in a given mood – low DLPFC
  - Improvise using a given pitch set – high DLPFC

Summary

- The involvement of the DLPFC in improvisation is lower for experienced improvisers
- Characteristics of the task also matter! (Pinho et al, 2015, Cereb Cortex)
  - Improvise in a given mood – low DLPFC
  - Improvise using a given pitch set – high DLPFC
- Different strategies for "creative thinking"?
  - Low top-down control - high level of task-specific expertise, allow spontaneous free association
  - High top-down control – lower level of task-specific expertise, free association not useful

General summary

- Artistic behaviors and professional artists are unique models for higher human cognition
- Music and expertise
  - →Expertise is multifactorial and depends on gene-environment interactions
  - →Twins are useful for studies of causal effects of long-term training
- Music and creativity
  - →Improvisation as a model for creative cognition
  - →Prefrontal involvement in creative thinking depends on training and task characteristics

Coworkers & collaborations

- Post-docs and alumni
  - →Miriam Mosing, Karin Verweij, Örjan de Manzano Helene Eriksson, László Harmat, Anders af Wåhlberg
- PhD students
  - →Ana Luísa Pinho, Diana Müssgens, Lars Forsberg
- IT, administration
  - →Pelle Karlsson, Louise von Essen
- Collaborations
  - →Nancy Pedersen, Töres Theorell (KI), Guy Madison (Umeå University)
  - →Zach Hambrick (Michigan State Univ), Mihály Csíkszentmihályi (Claremont Grad Univ), Mark Hallett (NIH), Miguel Castelo-Branco (University of Coimbra)

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